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CROP MANAGEMENT AND ANIMAL PRODUCTION IN YEARLY ROTATIONS UNDER INVERSION AND NO TILLAGE

Alan J. Franzluebbers[1*] and John A. Stuedemann[1]

[1]USDA–Agricultural Research Service, 1420 Experiment Station Road, Watkinsville GA 30677
*Corresponding author's e-mail address: afranz@uga.edu

ABSTRACT

Integration of crops and livestock could provide benefits to both crop and livestock production systems, as well as provide economic opportunities and environmental protection. We are currently in the middle of a multi-year study to evaluate the impacts of tillage, cover crop management, and timing of grazing animals on crop and livestock production characteristics. With soil organic matter at a high level following termination of perennial pasture, we determined crop yield and animal production during the first three growing seasons of two cropping systems (sorghum/rye and wheat/pearl millet) managed under conventional tillage (CT) or no tillage (NT) and whether cover crop was grazed by cattle or not. Sorghum grain yield during the first year (52% of normal precipitation) was lower under NT (10 bu/acre) than under CT (20 bu/acre). Wheat grain yield in 2003 (39 bu/acre) and sorghum grain yield in 2003 (63 bu/acre) were unaffected by tillage regime and whether previous cover crop was grazed by cattle or not. Ungrazed cover crop biomass production was 12% greater under NT than CT for millet in 2002, 23% greater under NT than CT for rye in 2003, and 82% greater under NT than CT for millet in 2003. Cattle live-weight gain was not statistically different between tillage systems, but average daily gains were 0.5 $\pm$ 0.2 lb/day greater under NT than under CT during the first three growing seasons. Results are yet incomplete to make a system-level assessment, but these initial results suggest that (1) NT is preserving the benefits of long-term accumulation of organic matter following perennial pasture and (2) no negative effect of cattle grazing cover crops is being carried over to subsequent grain crops.

INTRODUCTION

Soil organic matter is a critical component in maintaining soil quality in the southeastern USA. Pastures are known to improve soil organic C and N, which leads to retention of organically-bound nutrients and improved water relations. Cropping systems that are appropriate in this region under conditions of high soil organic matter have not been evaluated since much of the cropland has been stripped of soil organic matter from previous degradative cropping practices. Crop productivity response to tillage management following pasture termination may be significantly different than following a previously degraded land usage due to the presence of a large storage of nutrients, soil biological potential, and improved physical structure.

Climatic conditions in the Southern Piedmont are characterized by high precipitation-to-potential evapotranspiration during the winter growing season, but low precipitation-to-potential evapotranspiration during the summer growing season. The impact of time of grain cropping (i.e., spring versus summer) on grain yield, forage availability, and soil properties has not been well described, especially under conditions of initially high soil organic matter following pasture. Under a potentially double-cropping environment in the southeastern USA, a cover crop following grain cropping could provide high-quality forage to supplement shortages in supply from perennial pastures.

The impact of grazing animals on the environment is more often than not viewed as negative. A large portion of the land area in the Southern Piedmont USA is devoted to pasture production of cattle. Our previous work has shown that grazing of warm-season grasses in the summer can have positive impacts on soil organic C and N accumulation and no observable detriment to surface soil compaction (Franzluebbers et al., 2001). However, the role of grazing animals in pasture–crop rotations does not have to be limited to the medium- or long-term pasture phase alone. Cover crops following grain crops can be an excellent source of high quality forage to be utilized in small, mixed-use farming operations, such as those commonly found in the Southern Piedmont region. A potential impact of animals grazing cover crops, however, could be compaction due to hoof action, as observed in Southern Piedmont soils under relatively low soil organic matter conditions (Tollner et al., 1990). Surface residue cover may provide a significant buffer against animal trampling effects, such that no tillage crop production following long-term pasture could alleviate negative animal trampling effects.

Our objective was to quantitatively evaluate three management factors (i.e., tillage, time of grain cropping, and cover crop management) for their impacts on plant and animal productivity. The factorial arrangement of treatments allowed us to isolate interactions among management factors, which should lead to a better understanding of the processes controlling productivity and environmental quality. Specific objectives during the course of this mult-year project will be to (1) quantify the responses in plant and animal productivity due to tillage management under cropping systems that include grazing cattle and high cropping intensity, (2) quantify the relative stability of plant production during winter versus summer growing seasons, (3) quantify cattle productivity and performance during short-term grazing alternatives to perennial pastures, and (4) eventually to evaluate the interrelationships among soil properties following adoption of land management systems, which may alter soil organic matter dynamics and plant and animal productivity.

MATERIALS AND METHODS

The experiment is located at the J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville GA on Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludult). A set of 18 experimental paddocks (1.7 acres each) were previously arranged as six cattle grazing treatments in three blocks. Previous treatments included low (134-15-56 kg N-P-K $\cdot$ ha^{-1} $\cdot$ yr^{-1}) and high fertilization rates (336-37-139 kg N-P-K $\cdot$ ha^{-1} $\cdot$ yr^{-1}) imposed upon four grass variables ['Kentucky-31' tall fescue (*Festuca arundinacea* Schreb.) with low and with high endophyte infection, 'Johnstone' tall fescue with low endophyte infection, and 'Triumph' tall fescue with low endophyte infection]. Previous treatments were part of a long-term experimental design initiated in 1981 to study tall fescue–endophyte effects on cattle productivity, performance, and other miscellaneous animal response variables until 1997. Fertilization was terminated prior to 1998 and forage grazed on an *ad hoc* basis thereafter. Pasture growth during the past three years without fertilization was expected to remove any differences among paddocks in residual inorganic soil N. All paddocks were limed (1 ton/acre) immediately prior to termination of the tall fescue. The 18 experimental paddocks were regarded as an excellent starting point for the proposed research because soil organic matter was at a high level (Franzluebbers et al., 1999) and grazing infrastructure was mostly in place at the site (fencing, gates, shades, mineral feeders, watering troughs, and animal handling facility).

The experimental design of the current investigation consisted of a completely randomized design with a split-plot arrangement within main plots. Main plots were a factorial arrangement of (a) tillage and (b) time of grain cropping and split plots within main plots were (c) cover crop management. Main plots were replicated four times. Grazed plots were 1.1 acre in size and ungrazed plots were 0.6 acres. Two paddocks remained in perennial pasture to serve as uncropped controls.

Tillage management was with (1) conventional disk tillage (CT) following harvest of each grain and cover crop and (2) no tillage (NT) with glyphosate to control weeds prior to planting. Conventionally tilled plots were broken from sod with a moldboard plow to a depth of 10 to 12" and disk plowed (6 to 8") thereafter.

Cropping systems included (1) winter grain cropping [wheat (*Triticum aestivum* L.); November planting and May harvest] with summer cover cropping [pearl millet (*Pennisetum glaucum* (L.) R. Br.]; June planting and October termination) and (2) summer grain cropping [grain sorghum (*Sorghum bicolor* (L.) Moench]; May-June planting and October harvest) with winter cover cropping [cereal rye (*Secale cereale* L.); November planting and May termination]. 'Tifleaf 3' pearl millet was drilled in 6.75"-wide rows under CT and 7.5"-wide rows under NT at a rate of 14 lb/acre on 12 June 2002 and at a rate of 13 lb/acre on 26 June 2003. 'Pioneer 83G66' grain sorghum was drilled in 13.5"-wide rows under CT and 15"-wide rows under NT at a rate of 5 lb/acre from 13-14 June 2002 and at a rate of 6 lb/acre from 2-5 June 2003. Due to poor stand of sorghum in 2002, especially under NT, portions of plots were replanted on 17 July 2002. Ammonium nitrate was spread on sorghum and millet at 44 lb N/acre on 18 June 2002, on sorghum at 46 lb N/acre on 12 June 2003, and on millet at 40 lb N/acre on 9 July 2003. Sorghum was harvested for grain from 15-22 November 2002 and from 17-20 October 2003. 'Crawford' wheat was drilled in 7.5"-wide rows at a rate of 106 lb/acre on 28 November 2002 and '518W' wheat was drilled at 99 lb/acre on 4 November 2003. 'Hy-Gainer' rye was drilled in 7.5"-wide rows at a rate of 111 lb/acre on 2 December 2002 and at a rate of 102 lb/acre on 5 November 2003. Ammonium nitrate was spread on wheat and rye at 47 lb N/acre on 25 February 2003 and at 36 lb N/acre on 20 February 2004. Wheat was harvested for grain from 11-19 June 2003.

Cover crops were managed to assess the impact of grazing cattle on crop production as (1) without cattle by mechanical rolling at maturity and (2) stocking with cattle for 60-90 days to consume available forage produced. Cover crops were stocked with yearling Angus steers in Summer 2002 (initial weight 578 $\pm$ 48 lbs) and in Spring 2003 and with cow/calf pairs in Summer 2003 (initial cow weight 1107 $\pm$ 88 lbs and initial calf weight 370 $\pm$ 33 lbs). Ungrazed cover crops were grown until 2-4 weeks prior to planting of the next crop and either (1) mowed prior to conventional tillage operations or (2) mechanically rolled to the ground in the no-tillage system.

Each grain and cover crop received a top-dressing applications of ~40 kg $N \cdot ha^{-1}$ as ammonium nitrate shortly after planting and no other fertilizer amendment. The basal application of N assured early plant growth and development with further growth dependent upon the mineralization of stored nutrients in soil organic matter. Extractable P and K concentrations in the surface 3 inches of soil were greater than 100 mg $P \cdot kg^{-1}$ soil and 400 mg $K \cdot kg^{-1}$ soil, levels considered adequate for crop production (Schomberg et al., 2000).

Grain production was determined by weighing the contents of the entire experimental unit harvested with a field combine following unloading onto a truck with scales placed under all tires. A subsample of grain was collected for moisture determination. Yield was adjusted to 14% moisture for sorghum and 13.5% moisture for wheat. Standing stover following grain harvest was determined from 0.5- x 3.3-ft areas (3 in ungrazed plots and 5 in grazed plots). Cover-crop above-ground biomass was collected in the same manner. Grain, stover, and forage components were weighed before and after oven drying (131 EF). Stand count of crops beginning with the 3rd growing season

Table 1. Crop grain yield and standing stover as affected by cropping system, tillage, and cover crop management during the first three growing seasons on a Typic Kanhapludult in Watkinsville GA.

			Summer 2002		Spring 2003		Summer 2003	
Cropping system	Tillage	Cover crop	Grain	Stover	Grain	Stover	Grain	Stover
			bu/a	lb/a	bu/a	lb/a	bu/a	lb/a
Sorghum/rye	CT	Ungrazed	18	1687	-	6437	61	3167
		Grazed	23	1582	-	558	59	2538
	NT	Ungrazed	9	1933	-	7902	72	6524
		Grazed	11	2030	-	815	61	4508
LSD ($p = 0.05$)			9*	1184	-	1355*	21	1152*
Wheat/millet	CT	Ungrazed	-	4712	38	1152	-	3254
		Grazed	-	359	39	1256	-	171
	NT	Ungrazed	-	5256	38	1312	-	5907
		Grazed	-	873	40	1427	-	403
LSD ($p = 0.05$)			-	941*	7	344	-	2109*

were determined by counting plants in 2 adjacent rows 40" long at 3 locations in ungrazed plots and 5 locations in grazed plots.

Cattle live-weight gain was determined from initial and final weights during several 2-3-week stocking periods within each growing season. Live weights were shrunk body weights following 12-16 hours without water. Stocking density varied based on quantity of forage available. Animal unit days were adjusted to a common animal unit of 1102 lbs using the suggested power function of 0.75 (Forage and Grazing Terminology Committee, 1991).

The general linear model procedure of SAS was used to analyze variances for each of the plant and animal responses during each growing season separately (SAS Institute, 1990).

RESULTS AND DISCUSSION

Crop Production Characteristics - Sorghum/Rye Production System

The summer of 2002 (the first year of this study) continued to be drier than normal, just as it had been during the past 3 years. From 1 May 2002 until 13 September 2002, only 9.2" of rainfall was received (52% of normal precipitation for this period). Sorghum production during the first growing season (Summer 2002), therefore, was very low in both tillage systems (Table 1). Perhaps due to the unusually dry conditions, sorghum grain yield was statistically lower with NT than with CT in 2002. It is possible that soil moisture from deeper in the profile was redistributed for utilization early in the growing period when tilled. Standing sorghum biomass at the end of the growing season was not different between tillage systems.

Rainfall from 1 October 2002 to 30 April 2003 was 29.0", the same as the long-term normal for this period. Rye dry matter production without cattle grazing was 23% greater under NT than under CT during this period (Table 1). A combination of moisture and nutrient conservation may have contributed to this difference in production between tillage systems. Stocking cattle on the rye cover crop reduced standing forage at the end of the growing season to ~10% of total above-ground production under both tillage systems.

In Summer 2003, rainfall from 1 May to 30 September was 26.1", which was 6.4" greater than the long-term normal for that period. Grain yield of sorghum averaged 63 bu/acre, with no differences due to tillage regime or previous exposure of cover crop to grazing animals (Table 1). Standing sorghum biomass as the end of the growing season averaged 93% greater under NT than under CT when averaged across cover crop management systems. There was a significant interaction between tillage and cover crop management on sorghum stover, due to a greater difference between tillage systems without (106%) than with (78%) cattle grazing. It is possible that the conservation of surface-soil nutrients under NT compared with the rapid mineralization and previous utilization of nutrients with under CT may have contributed to the difference in sorghum stover production. Due to the relatively abundant precipitation in 2003, it is unlikely that conservation of water with NT was a major factor that contributed to this difference in stover.

Plant population of sorghum in July 2003 averaged $2.5 ft^{-2}$ and was not different among tillage regimes and cover crop management (Table 2). Likewise, rye population averaged $13.7 \cdot ft^{-2}$ and was not different among tillage regimes and cover crop management. These data provide evidence that soil surface conditions could be suitably managed to provide adequate seedling emergence under both tilled and untilled conditions, as well as when cattle have grazed a previous cover crop or not.

Wheat/Millet Production System

Despite the dry conditions in Summer 2002, millet biomass production averaged 4984 lb/acre without cattle grazing and was not affected by tillage regime (Table 1). Cattle grazing of the millet reduced standing millet biomass at the end of the growing season to 8% under CT and 17% under NT.

In Spring 2003, wheat grain yield averaged 39 bu/acre and was not different between tillage systems (Table 1). Standing wheat biomass at the end of the growing season averaged 1287 lb/acre and was not affected by tillage regime or cover crop management. Wheat yield response to no-tillage management has been variable in the southeastern USA. On a Cecil sandy loam in Georgia under a wheat/sorghum cropping system, wheat grain yield during 4 years averaged 46 bu/acre under CT and 47 bu/acre under NT (Langdale et al., 1984). In South Carolina under a wheat/soybean cropping system, wheat grain yield during 2 years averaged 54 bu/acre under CT and 56 bu/acre under NT (Frederick and Bauer, 1996). In North Carolina under a wheat/soybean-corn rotation, wheat grain yield during two years averaged 56 bu/acre under CT and 52 bu/acre under NT at a Piedmont location and 51 bu/acre under CT and 49 bu/acre under NT at a Coastal Plain location (Wagger and Denton, 1989).

Table 2. Plant population (plants · ft^{-2}) as affected by cropping system, tillage, and cover crop management during the 3rd and 4th growing seasons on a Typic Kanhapludult in Watkinsville GA.

Cropping system	Tillage	Cover crop	July 2003	December 2003
Sorghum/rye	CT	Ungrazed	2.5	13.6
		Grazed	2.5	13.0
	NT	Ungrazed	2.4	13.5
		Grazed	2.8	14.7
LSD ($p = 0.05$)			0.5	2.7
Wheat/millet	CT	Ungrazed	10.4	14.6
		Grazed	10.5	12.9
	NT	Ungrazed	6.7	12.4
		Grazed	6.4	16.4
LSD ($p = 0.05$)			3.3*	1.6*

In Summer 2003, millet biomass production without cattle grazing was 82% greater under NT than under CT (Table 1). Greater millet biomass under NT than under CT in 2003 was consistent with the production difference in sorghum biomass in 2003, pointing to a consistency in the possibility for greater conservation of nutrients with NT during these first three growing seasons following termination of perennial pasture. Millet utilization by grazing cattle was greater in 2003 (93-95%) than in 2002 (83-92%).

Plant population of millet in July 2003 was ~37% lower under NT than under CT, whether system was grazed or not (Table 2). It is not likely that the reduced plant population was the reason for the enhanced millet biomass production with NT (Table 1). These data do suggest that tillering in millet is significantly vigorous to compensate for reduced plant stand with NT, perhaps due to inadequate seed/soil contact with abundant surface residue mulch. Plant population of wheat in December 2003 was 15% lower under NT than under CT in ungrazed plots, but 27% greater under NT than under CT in grazed plots (Table 2). It is possible that the large quantity of previous millet biomass laying on the soil surface under NT may have prevented adequate seed/soil contact for optimum wheat germination and development. Since millet biomass was grazed and processed through cattle, there would have been less surface residue mulch to inhibit wheat seedling development in grazed plots. During 2 years on a Goldsboro sandy loam, wheat population averaged 25 plants · ft^{-2} under CT and 21 plants · ft^{-2} under NT (Frederick and Bauer, 1996).

Cattle Production Characteristics

Cattle live-weight gain during Summer 2002 averaged 444 lb/acre and was not different between tillage systems (Table 3). Despite the abnormally low precipitation, millet biomass production was excellent, resulting in stocking of cattle for 11 weeks with an average of 1.8 animal units/acre under CT and 1.6 animal units/acre under NT. Average daily gain was 3.1 lb/day under CT and 3.6 lb/day under NT. Compared with the control paddocks containing perennial grass (total gain of 252 lb/acre, 1.1 animal units/acre, 3.0 lb gain/day), cattle performance and production was improved even under these relatively dry first-year conditions.

Table 3. Cattle live-weight gain (lb/acre) and animal unit days (AUD) as affected by cropping system and tillage during the first three growing seasons on a Typic Kanhapludult in Watkinsville GA. Note: Yearling steers stocked in Summer 2002 and Spring 2003 and cow/calf pairs stocked in Summer 2003.

Cropping system	Tillage	Summer 2002		Spring 2003		Summer 2003		
		Gain	AUD	Gain	AUD	Cow gain	Calf gain	AUD
Sorghum/rye	CT	-	-	234	70	-	-	-
	NT	-	-	278	70	-	-	-
LSD (p = 0.05)		-	-	68	0	-	-	-
Wheat/millet	CT	443	142	-	-	100	181	118
	NT	446	125	-	-	123	204	123
LSD (p = 0.05)		99	14*	-	-	180	73	10

In Spring 2003, grazing season length was relatively short due to a combination of factors including late planting of rye cover crop and the need to improve fencing for future handling of cow/calf animal units, which delayed stocking until 25 March 2003. Cattle live-weight gain averaged 256 lb/acre and was not different between tillage systems (Table 3). Stocking rate was 1.7 animal units/acre for 6 weeks. Average daily gain was 3.3 lb/day under CT and 4.0 lb/day under NT.

In Summer 2003, cow live-weight gain averaged 111 lb/acre and was not different between tillage systems (Table 3). Calf live-weight gain was also not different between tillage regimes, averaging 192 lb/acre. Stocking rate averaged 2.1 animal units/acre for 8 weeks. Grazing season was shorter in 2003 than in 2002 partly because of a difference in animal class, in which cow/calf units were stocked in Summer 2003 and utilized hereafter. Stocking with cow/calf pairs resulted in a minimal animal unit size of 1.44 compared with 0.62 for yearling steers. Average daily gain of cow/calf pairs was 2.4 lb/day under CT and 2.7 lb/day under NT.

CONCLUSIONS

An evaluation of converting perennial pasture to different annual cropping systems with multiple objectives to achieve grain and cattle production has been initiated and is partly completed. We have planned this evaluation to last 3 years, but may extend this timeframe. Through the first 1.5 years, crop production characteristics have been generally improved with NT compared with CT, especially with regards to plant biomass production for cattle consumption. The impact of cattle grazing previous cover crops on grain yield has been minimal. Although not significant in any of the individual growing seasons, cover crop utilization as forage has led to a trend for greater cattle performance and production under NT compared with CT. At the end of this evaluation, we plan an integrative assessment of crop and livestock production, environmental, and economic outcomes of these systems. Such an assessment should lead to better knowledge of how crops and livestock can be integrated for profit and environmental protection.

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REFERENCES

Forage and Grazing Terminology Committee. 1991. Terminology for grazing lands and grazing animals. Pochahontas Press, Inc., Blacksburg, VA. 38 p.

Franzluebbers, A.J., N. Nazih, J.A. Stuedemann, J.J. Fuhrmann, H.H. Schomberg, and P.G. Hartel. 1999. Soil carbon and nitrogen pools under low- and high-endophyte-infected tall fescue. Soil Sci. Soc. Am. J. 63:1687-1694.

Franzluebbers, A.J., J.A. Stuedemann, and S.R. Wilkinson. 2001. Bermudagrass management in the Southern Piedmont USA. I. Soil and residue carbon and sulfur. Soil Sci. Soc. Am. J. 65:834-841.

Frederick, J.R., and P.J. Bauer. 1996. Winter wheat responses to surface and deep tillage on the southeastern Coastal Plain. Agron. J. 88:829-833.

Langdale, G.W., W.L. Hargrove, and J. Giddens. 1984. Residue management in double-crop conservation tillage systems. Agron. J. 76:689-694.

SAS Institute. 1990. SAS user's guide: Statistics. Version 6 ed. SAS Inst., Cary, NC.

Schomberg, H.H., J.A. Stuedemann, A.J. Franzluebbers, and S.R. Wilkinson. 2000. Spatial distribution of extractable phosphorus, potassium, and magnesium as influenced by fertilizer and tall fescue endophyte status. Agron. J. 92:981-986.

Tollner, E.W., G.V. Calvert, and G. Langdale. 1990. Animal trampling effects on soil physical properties of two Southeastern U.S. ultisols. Agric. Ecosystems Environ. 33:75-87.

Wagger, M.G., and H.P. Denton. 1989. Tillage effects on grain yields in a wheat, double-crop soybean, and corn rotation. Agron. J. 81:493-498.